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Close together or far apart? The geography of host country knowledge sourcing and subsidiary's innovation performance

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Abstract

We investigate the influence of the geography of host country knowledge sources developing different types of knowledge on the quality and generality of a foreign subsidiary innovation. We suggest that the quality of subsidiary innovation is greater when more familiar knowledge is sourced in distant host country locations. We also argue that the generality of subsidiary innovation is greater when less familiar knowledge is sourced from not too distant host country locations because the novel combination potential is limited when source and recipient are close together and codification becomes too complex when they are far apart. We test our arguments on a sample of US subsidiaries of the top European and Asian multinationals operating in the global semiconductor industry and find support for our arguments.

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We investigate the influence of the geography of host country knowledge sources developing different types of knowledge on the quality and generality of a foreign subsidiary innovation. We suggest that the quality of subsidiary innovation is greater when more familiar knowledge is sourced in distant host country locations. We also argue that the generality of subsidiary innovation is greater when less familiar knowledge is sourced from not too distant host country locations because the novel combination potential is limited when source and recipient are close together and codification becomes too complex when they are far apart. We test our arguments on a sample of US subsidiaries of the top European and Asian multinationals operating in the global semiconductor industry and find support for our arguments.

INTRODUCTION

Knowledge creation within the multinational corporation (MNC) increasingly takes place in foreign subsidiaries, which can tap into the host country's knowledge base to source new valuable ideas and expertise (Bartlett and Ghoshal 1986, Frost et al. 2002, Gupta and Govidarajan 1994). Access to external knowledge sources in their respective host countries enables foreign subsidiaries not only to contribute to the MNC innovation processes (Almeida, 1996; Singh, 2007), but also fosters subsidiary innovation performance (Phene and Almeida, 2008).

External knowledge sources are not all alike (Kline and Rosenberg, 1986; Lundvall, 1988, Chesbrough, 2003; Laursen and Salter, 2006) and may differ along two dimensions: the *nature of the knowledge* that source and recipient traditionally develop and are familiar with, and the *geographical distance* between source and recipient (Vega-Jurado, Gutiérrez-Gracia, and Fernández-de-Lucio, 2009, Phene and Almeida, 2008; Almeida et al., 2003). Foreign subsidiaries can be more or less able to access and relate to different types of knowledge sources in their respective host countries depending on the subsidiary familiarity with the type of knowledge to be sourced (Cohen and Levinthal, 1990; Phene and Almeida, 2008). In addition, subsidiaries ability to source knowledge critically depends on the geographical distance from the host country knowledge sources (Frost, 2001; Criscuolo et al., 2005; Almeida 2003). Geographical distance may exacerbate knowledge codification problems as well as offer opportunities for novel knowledge combination (Adams and Jaffe, 1996; Adams, 2002; Audretsch and Feldman 1996; Cantwell, 1995; Cantwell and Santangelo 1999; Patel and Vega, 1999). Hence, the extent to which external knowledge sourcing by a foreign subsidiary in its host country hampers or facilitates the subsidiary innovation performance is a complex issue. Yet, we lack an understanding of *how different types of host country's knowledge sources located at different geographical distances from a foreign subsidiary influence the subsidiary innovation performance*.

To advance research in international knowledge sourcing, we investigate the effect of the geographical distance of host country industrial firms and research institutions from a foreign subsidiary on the subsidiary's innovation performance. To this end, we unpack subsidiary's innovation performance into quality and generality of innovation (Trajtenberg et al., 1997; Henderson et al., 1998) and, based on a well established economic literature, rely on the idea of a division of labor between research institutions, that perform most of the basic research, and industrial firms, that develop the bulk of applied knowledge (Arrow 1962, Nelson 1959).[1] On these premises, we argue that the quality of subsidiary's innovation increases as the geographical distance of the industrial host country knowledge sources increases because of the subsidiary's familiarity with the type of knowledge this external source traditionally develops, and the opportunity to access to diverse ideas and expertise from distant locations. We also suggest that the relationship between the geographical distance from research institutions and the generality of subsidiary innovation is inverted U-shaped. Sourcing from host country actors that traditionally developed less familiar knowledge bears great potential for knowledge recombination and ultimately enhances the generality of subsidiary innovation when these actors are geographically not too distant. As the geographical distance between host country research institutions and the subsidiary further increases, the generality of subsidiary innovation starts decreasing because codification of less familiar knowledge becomes progressively more complex across space.

We test and find support for our arguments using data on the United States Patent and Trademark Office (USPTO) patent portfolios of a sample of US subsidiaries of the top European and Asian MNCs operating in the global semiconductor industry between 1985 and 2000. The semiconductor industry offers an ideal test-bed for our hypotheses. During the studied period, non-US firms start operating in the industry and their activities significantly spread at a global level targeting mainly the US (Phene and Almeida, 2008) in order to source foreign knowledge in major industry technological clusters from industrial firms as well as universities and research centers (Phene and Almeida, 2008; Almeida, 1996; Perri and Andersson, 2014).

The study contributes to research on international knowledge sourcing by MNC foreign subsidiaries. First, we add to this stream of research by suggesting the continuous nature of geographical distance, which is an aspect so far investigated in terms of discrete discontinuity (Almeida et al., 2003). Second, we shed light on the heterogeneity of host country knowledge sources, which have been studied as a uniform agent (Frost, 2001; Almeida and Phene, 2004; Song and Shin, 2008). Finally, we investigate subsidiary innovation performance by accounting for the complexity and multi-dimensionality of this concept.

[1] We do recognize that industrial firms do perform basic research but this activity remains residual and unintentional (Rosenberg 1990).

THEORY AND HYPOTHESES

Subsidiaries have become increasingly central in the process of globalization of innovation (Phene and Almeida, 2008) and their innovation performance is critical for the competitive advantage of the entire MNC. Innovation performance is a complex and multi-dimensional concept (Vanhaverbeke et al., 2014) as the tremendous variation in the outcomes of the R&D process reflects (e.g., Trajtenberg, 1990; Trajtenberg et al., 1997; Hall, Jaffe, and Trajtenberg, 2001; Gambardella, Harhoff, and Verspagen, 2008). In particular, innovation performance can be unpacked into quality and generality (Trajtenberg et al., 1997; Henderson et al., 1998). Quality of innovation denotes the extent to which an invention has spurred and facilitated future technical advances (Henderson et al., 1998). It is strictly associated to the monetary value of the innovation and contributes to the firms' market value (Trajtenberg, 1990; Hall et al. 2005). Generality of innovation denotes the degree to which follow-up inventions that build upon the focal innovation are spread across diverse technologies (Trajtenberg et al., 1997). Hence, this aspect of innovation performance captures the applicability of the innovation across scientific and technological fields.

Variation in the innovative performance of MNC subsidiaries has been widely documented mainly in terms of size and, more recently, of quality of innovation, and related to the subsidiary's ability to source host country external knowledge (e.g., Frost, 2001; Almeida and Phene, 2004; Cantwell and Mudambi 2005; Phene and Almeida, 2008; Collinson and Wang, 2012). Arguably, the sourcing ability of the foreign subsidiary critically depends on the nature of the knowledge to be sourced and the geography of the source within the host country (Vega-Jurado, Gutiérrez-Gracia, and Fernández-de-Lucio, 2009; Phene and Almeida 2008; Almeida et al., 2003).

Research in the innovation study literature has traditionally distinguished between basic and applied knowledge (Nelson, 1982). Applied knowledge is closer to the bodies of practice, is more focused on technical questions, aims to solve particular technical problems and is close to the market (Kuhn 1962; Rosemberg 1982). This knowledge is typically developed by industrial firms, and yields immediate and likely returns. Basic knowledge is closer to the bodies of science, is more focused on scientific questions, elucidates general laws, has an impact across a broad range of fields and is less close to the market (e.g. Kuhn, 1962; Rosenberg, 1982). This knowledge is usually developed by research institutions (e.g. universities, research centers and other public innovative organizations) because of appropriability problems (Adams 1962, Nelson 1959).

Like other industrial firms, foreign subsidiaries are more familiar with the development of applied knowledge, which they have a greater understanding of and have eventually to protect from spillovers to their peers (Cantwell and Santangelo 2002; Narula and Santangelo 2009). Familiarity with the sourced knowledge facilitates absorptive capacity because it creates a common cognitive background (Cohen and Levinthal 1990), but at the same time it may favor redundancy as it limits access to diverse ideas and expertise (Noteboom 2000).

Geographical distance from host country knowledge sources bears also greater implications for the subsidiary ability to source knowledge. Sourcing knowledge from distant agents requires great efforts and, hence, ends up being costly due to codification problems and the resulting distance decay of knowledge spillovers (Bathelt et al. 2004, Amin and Cohedet 2004). At the same time, geographical distance may facilitate access to diverse ideas and expertise (Cantwell 1995; Singh 2008; Cantwell and Santangelo 1999; Patel and Vega 1999). Instead, knowledge developed by geographically proximate actors can be more easily (although not automatically) sourced, as proximity eases knowledge spillovers (Adams and Jaffe 1996; Adams 2002; Audretsch and Feldman 1996), but it may also favor redundancies (McFadyen and Cannella 2005).

To account for the influence of both dimensions of knowledge sourcing within the host country borders on subsidiary innovation performance, we relate the geographical distance of host country industrial firms and research institutions from a focal subsidiary to the quality and generality of the subsidiary's innovation, respectively.

Knowledge sourcing from industrial firms

Industrial firms are typical external knowledge sources of foreign subsidiaries. Access to knowledge spillovers from host country firms is indeed a critical input to the innovation process of MNC's subsidiaries (Almeida, 1996; Frost, 2001; Phene and Almeida 2008). The type of knowledge industrial (host country and foreign) firms traditionally develop is applied knowledge. The specialization and competences of both host country firms and foreign subsidiaries with applied knowledge enhance the familiarity and, hence, the absorptive capacity of each other knowledge (Cohen and Levinthal, 1990). In particular, the similar nature of the knowledge developed by foreign subsidiaries and host country industrial firms enables foreign subsidiaries to have a good understanding of the knowledge they can source from these local sources.

However, sourcing knowledge from host country firms may hinder the quality of the innovation of the foreign subsidiary when these firms are located in close proximity to the foreign subsidiary. The set-up of a subsidiary in the proximity of industrial peers may be driven by the desire to closely monitor the peer's innovative activities and be up to date with the latest knowledge development in the sector relevant technologies (Narula and Santangelo 2009). Yet, geographically close companies are likely to develop very similar familiar knowledge outputs and, hence, the knowledge sourced by proximate peers may be redundant (McFadyen and Cannella 2005). In addition, proximity may favor unintended knowledge spillovers to the nearby firms (Cantwell and Santangelo, 2002) and, hence, the innovation performance of each firm is not different from that of the nearby peers (Lahiri 2010, 2015). The knowledge sourced from proximate firms may also not be of high quality due to the adverse selection of less innovative firms in agglomerations (Alcacer 2006). This discussion suggests that foreign subsidiaries can find more advantageous to source applied knowledge from geographically distant industrial firms to ultimately enhance the quality of subsidiary innovation. The knowledge developed by distant industrial firms is still easy to absorb across space because it is familiar to the foreign subsidiary and, at the same time, may inspire novel combinations of specialized knowledge by facilitating access to diverse ideas and expertise developed in far away locations (Singh, 2008).

Instead, the geographical distance of industrial firms from which the subsidiary sources knowledge is unlikely to influence the generality of subsidiary innovation as these external knowledge sources traditionally aim at the refinement and specialization rather than the broad applicability of the knowledge developed.

Hence, we suggest that the quality of subsidiary's innovation will increase with the geographical distance of host country industrial firms from which the subsidiaries sources knowledge.

Hypothesis 1: The quality of subsidiary innovation increases as the geographical distance of the subsidiary from industrial host country knowledge sources increases.

Knowledge sourcing from research institutions

Foreign subsidiaries are especially eager to establish partnerships with host country universities and research centers to access basic knowledge, which they are reluctant to invest in due to appropriability problems (Arrow, 1962). This type of knowledge is substantially different from the applied knowledge that foreign subsidiaries develop and this dissimilarity raises scope for synergies between the two types of knowledge (Agarwal and Ohyama 2013). In particular, the knowledge sourced from host country research institutions may enhance the subsidiary combinatory capability and facilitate novel knowledge combinations with wide applicability (Kogut and Zander 1992). This combination potential is further amplified when host country research institutions are not too distant from the foreign subsidiary. In these situations, the generality of subsidiary innovation is likely to increase because the knowledge sourced is dissimilar from the type of knowledge the subsidiary traditionally develops, and, at the same time, diverse from the basic knowledge available in the subsidiary close proximity. In addition, when the source is not too far away, the subsidiary is able to deal with the codification of basic knowledge across space. The subsidiary could figure out the usefulness of such knowledge for its innovative activities more easily through face-to-face exchanges. Instead, basic knowledge developed in close proximity, although dissimilar from the type of knowledge the subsidiary traditionally deals with, and easier to codify, is likely to bear little innovative potential because proximate relationships favor the development and sharing of redundant knowledge, which collocated peers can also exploit (McFadyen and Cannella 2005). At the same time, the limited familiarity of the foreign subsidiary with basic knowledge may create codification problems when host country research institutions are too far. In this case, it becomes difficult to bridge the cognitive barriers between the source and the recipient, and knowledge sourcing from distant host country research institutions will hinder the generality of subsidiary innovation.

Hence, we suggest that, as the geographical distance between the foreign subsidiary and host country research institutions initially increases, the effect of the potential for knowledge combinations will offset the problems of codifying less familiar knowledge and the generality of subsidiary's innovation will increase, but up to a point. After that point, further increases of geographical distance between source and recipient will exacerbate the codification problems of less familiar knowledge, which will prevail over the effect of the novel knowledge combination potential.

Instead, the geographical distance of host country research institutions from which the subsidiary sources knowledge is unlikely to influence the quality of subsidiary innovation as the knowledge developed by research institutions hardly contributes to innovation outputs that yield immediately returns and higher market value.

Hence, we suggest that the generality of subsidiary's innovation will initially increase with the geographical distance of host country research institutions from which the subsidiary sources knowledge, but up to a point. After that point, the generality of subsidiary's innovation will start decreasing as the subsidiary geographical distance from these host country research institutions further increases.

Hypothesis 2: The relationship between the generality of subsidiary innovation and the geographical distance of the subsidiary from host country knowledge sources of the research institution type is inverted U-shaped.

DATA AND METHODS

Data

To test our hypotheses, we analyzed the whole set of patents belonging to US-based subsidiaries of leading European and Asian semiconductor firms over the years 1985-2000.

The semiconductor industry is an appropriate empirical setting since it is one of the most technology intensive industries, where knowledge is highly distributed worldwide. During the period of analysis, non-US firms start operating in the industry and their activities became increasingly global (Phene and Almeida, 2008). The strategic intent was to learn about foreign knowledge from a variety of actors, including competitors, customers, suppliers and universities in important industry technological clusters such as those in Santa Clara (California) and in the tri-state New York-New Jersey-Connecticut area (Phene and Almeida, 2008; Almeida, 1996; Perri and Andersson, 2014). Given the technological intensive nature of the industry, semiconductors companies extensively rely on patents for both defensive and other strategic reasons (Hall and Ziedonis, 2001). Early studies have suggested that, regardless of their home country, every major semiconductor MNC is likely to hold a comprehensive portfolio of US patents, which reflects its innovative activity (Almeida & Kogut, 1999). Hence, to analyze firms' sourcing and innovative behavior we use data on US patents, and their respective backward and forward citations. In addition, the focus on a single host country enables to hold constant cultural and language differences (Phene et al. 2006), which may influence knowledge transmission and sourcing among geographically distant actors.

Patent citations are reported in the patent document, which also includes information on the organization to which the patent's ownership is assigned, the geographic location of the inventor, the patent application and grant date and the technological class in which the patent has been classified. The inclusion of a list of citations to other patents in the patent document is mandatory in the US patent system (Almeida, 1996) and such a list serves the objective to identify the technological antecedents to the specific innovation. These technological antecedents represent the knowledge inputs that innovators have combined to generate the new technology, and therefore allow tracing the geographic origin of the knowledge sources utilized for innovation.

The use of patent citation data to investigate firms' innovative behavior entails potential limitations. First, patents represent *codified* technology and accordingly do not allow capturing the flow of tacit knowledge. However, this limitation is alleviated by the fact that, according to previous literature, codified and tacit knowledge flows tend to be correlated and complementary (Mowery et al., 1996). An additional concern deals with examiner-added citations as not all citations covered in the patent document are included voluntarily by the inventor(s). Rather, some citations might have been added by the office examiner. Unfortunately, we do not have the possibility to identify these citations, as the distinction between examiner-added citations and inventor citations is not available for patents granted before 2001 (Alcacer and Gittelman, 2006). However, examiner-added citations are also likely to represent knowledge sources that the firm has used, though unconsciously (Breschi and Lissoni, 2005). In other words, "*some citations represent direct technological influences on a particular innovation, while other citations may only represent indirect technological influences (since the patent examiner added them)*" (Almeida and Kogut, 1999, p. 908). In addition, an established empirical literature, which has used patent citation data to infer knowledge flows, acknowledges confidence on the general significance of patent citations regardless the origin of the citations in the patent document (Jaffe *et al.*, 1993; Fogarty *et al.*, 2000; Branstetter, 2006)

Our sample concerns the patents of US-based subsidiaries of the top 11 European and Asian semiconductor MNCs by sales in year 2005. To identify this sample, we followed a standard procedure in international business literature (Almeida, 1996; Almeida and Phene, 2004; Phene and Almeida, 2008; Lahiri, 2010, 2015; Perri and Andersson, 2014). In particular, we first compiled the list of these firms using information from Gartner Dataquest. Then, combining information from the USPTO database, the NBER US Patent Citation Data File (Hall et al., 2001) and the Harvard Patent Dataverse (Li et al. 2014), we identified all utility patents that (i) had been assigned to our sample MNCs, (ii) whose first inventor had a US-based address between 1985 and 2000, and (iii) whose technological class belongs to the four Derwent patent classes included in the section ''Semiconductors and Electronic Circuitry'' (Alcacer & Zhao, 2012): U11 (semiconductor materials and processes), U12 (discrete devices), U13 (integrated circuits) and U14 (memories, film and hybrid circuits). In turn, these Derwent classes correspond to the following US technological classes: H01L (semiconductor devices; electric solid state devices not otherwise provided for), C30B (single-crystal growth), G11C (static stores). This process leads to a total number of 1,788 patents analyzed.

Measures

Dependent variables

Quality of subsidiary innovation has been traditionally measured as the number of forward citations received by a focal patent (Trajtenberg, 1990; Henderson et al., 1998; Hall and Ziedonis, 2001). The intuition behind this measure is that the more a patent is used in subsequent innovation, the higher its importance and the economic value to the innovator (Hall et al., 2000; Gittelman and Kogut, 2003, Harhoff et al., 1999, Lanjouw and Schankerman, 1999 and Hall, Jaffe, and Trajtenberg, 2000). This measure is indeed correlated with the "*private value of the patentable invention*" (Hall and Ziedonis, 2001; p. 123), and indicates economic success since the subsequent patents citing a focal innovation "*are the result of costly innovation efforts undertaken mostly by profit-seeking agents*" (Trajtenberg, 1990; p. 174). In addition, firms with more heavily cited patents also experience economic benefits (Trajtenberg, 1990) and enjoy on average higher stock market values (Hall et al., 2001).

When using citation-based measures, it is important to consider that citations may depend on the focal patent's vintage. Older patents are exposed to the likelihood of forward citations for a longer period of time and, hence, are likely to be cited more than younger patents, for reasons that are independent on their inherent quality. To address this "right-truncation" problem, we followed previous studies (Mowery and Ziedonis, 2002; Phene and Almeida, 2008; Arts and Veugelers, 2015) and restricted forward citations to those occurring within 3 years from the focal patent's application date

(Sterzi, 2013). The choice of this time frame is deliberate and consistent with our industry setting. In the semiconductor industry, the duration of the product life cycle is not larger than 3 years according to Moore's law (1965). Thus, a time window of observation greater than 3 years is likely to overstate the time span during which a given innovation is on the frontier of the technology in the industry (Stuart and Podolny, 1996). Finally, the citations a patent receives in the very early stage of its life are more strongly correlated with the patent's economic value, as they signal "*the presence of others working in a similar area, and thus that the area is expected by others to generate economic value*" (Lanjouw and Schankerman, 1999, p. 7). For instance, recent research shows that, compared to university patents, corporate patents receive a higher number of forward citations in the first years after application, as the latter are more closely associated with commercial returns in the short-term. This citation premium shrinks, and eventually disappears, when considering longer time intervals (Sterzi, 2013).

Based on previous studies by (Trajtenberg et al., 1997; Hall et al. 2001), we measure the generality of subsidiary innovation as follows:

$$\textit{Generality of subsidiary innovation}_i = 1 - \sum_j^{n_i} s_{ij}^2 \qquad (1)$$

where s_{ij} indicates the percentage of citations received by patent i that belong to the technological class j, out of n_i patent technological classes. Patents that are cited by subsequent patents that belong to a wide range of technologies will score high in terms of generality, because they have an influence on a more diverse set of technological fields (Argyres and Silverman, 2004; Valentini, 2012). In other words, these patents have been used as an input in processes that have resulted in a set of technologically widespread innovations. In particular, we drawn on a number of previous studies (Argyres and Silverman, 2004; Singh, 2008; Valentini, 2012) and consider 36 two-digit technological classes proposed by Hall et al. (2001). By definition, this measure can be calculated only for those patents with at least one forward citation (Mowery and Ziedonis, 2002).[2]

Also in this case, following previous research (Mowery and Ziedonis, 2002; Sterzi, 2013), we want to account for the potential "right-truncation" problem associated with forward citations. However, since the generality measure is meant to capture the

[2] Given the specificities of this measure, the sample used to estimate *generality of subsidiary innovation* is smaller than the one used to estimate in *quality of subsidiary innovation* (Mowery and Ziedonis 2002).

extent to which an innovation is able to instigate successive inventions across a wide-range of technological fields, it is important to allow for longer citation lags that allow to observe a more comprehensive set of follow-up inventions potentially building on our sample patents. In fact, inventions incorporating less related technologies are likely to be more complex and basic, and thus may take more time to manifest (Czarnitzki et al., 2012). Following this logic, we consider forward citations used to compute our generality measure to those occurring within 5 years of the focal patent application date. Yet, the generality measure may be biased due to the fact that the higher the number of citations a patent receives, the greater the likelihood that these forward citations will be spread across a larger number of technological classes (Hall et al. 2001). This bias is more severe for patents with a small number of forward citations (i.e. a patent with a single forward citation will have a value of generality equal to 0 by definition). To correct for this bias, we followed the method proposed by Hall et al. (2001), and multiplied the generality measure by $n/(n-1)$, where n is the number of forward citations that a focal patent has received during the first 5 years following its filing date.

Independent variable

To proxy the extent to which a foreign subsidiary sources knowledge from geographically distant host country actors, we rely on the outcomes of such sourcing behavior, as represented by patent citations (Almeida and Phene, 2004; Frost and Zhou, 2005; Zhao, 2006; Phene and Almeida, 2008; Singh, 2008; Lahiri, 2010, 2015; Perri and Andersson, 2014). Following Frost (2001), we assume that the subsidiaries' ability to leverage different sources of knowledge may be inferred by looking at the pattern of citations to previous patents referenced by the subsidiary focal patents.

To build our variables, we first identified all the citations to patents that do not belong to the MNC of the focal subsidiary in order to focus on "external" knowledge sources. To this end, we compare the MNC assignee identifier provided by the NBER database (Hall et al., 2001) with the identifier of the assignees to which the subsidiary's patents refer as backward citations, and through a further manual check performed by the authors. From this sample of backward citations, we retained only those patents whose first inventor was located in the US, as we are interested in the within-host country knowledge sourcing behavior of our subsidiaries.

Then, since we want to account for the nature of the sourced knowledge we distinguish host country knowledge sources between industrial firms and research institutions based on the NBER classification of the types of assignee (Hall et al., 2001).

The *industrial firms* category includes both foreign and US private corporations, and the *research institutions* category includes both foreign and US government, institutes and universities.[3]

For each of the two sets of backward citations, we develop measures of the extent to which they are geographically distant from the subsidiary within the host country borders. First, we assigned each *focal patent* to a US metropolitan statistical area/consolidated metropolitan statistical area (MSA/CMSA). To this end, we use the concordance data made available by Thompson[4] (2006) to map first inventors' US addresses as reported in the patent documents to metropolitan areas. For US addresses that could not be matched to metropolitan areas, we followed the standard procedure of defining a "phantom area" per each state (Agrawal et al., 2006; Thomson, 2006; Singh, 2008). Second, we divided the *backward citations* in three groups, depending on whether the cited patent's first inventor was located in the same subsidiary's MSA/CMSA, in the same subsidiary's US State (excluding inventors located in the same MSA/CMSA) or elsewhere in the US. The distinction between these three geographical units is consistent with the evidence of localized spillovers at the level of each unit as well as with the existence of border effects across the units (Singh and Marx, 2013). Then, for each of the three geographical groups of backward citations, we calculated the average distance between the focal subsidiary and the knowledge sources in that group in two steps. First, we geocoded the location of both focal and cited patents (i.e., we identified the latitude and longitude coordinates of their first inventors' addresses). Then, we calculated the travel time via driving[5]. Following this procedure, we built our measure of geographical distance from host country knowledge sources (*Geodistance*) as follows:

$$Geodistance_{xy} = [(AD_M + 1) * p_{iM}] + [(AD_S + 1) * p_{iS}] + [(AD_C + 1) * p_{iC}] \quad (2)$$

[3] Examples of "foreign and US governments" are the French Agence Nationale de Valorisation de la Recherche (ANVAR) and the US Army Medical Research and Materiel Command, respectively; examples of "foreign and US institutes" are the Electronics and Telecommunications Research Institute of Korea and the Purdue Research Foundation, respectively.

[4] Data are available at http://www.peterthompson.gatech.edu

[5] Both the geocoding and the computation of the travel time have been performed using commands downloadable in Stata 12. Both commands use Google Maps for providing spatial information for data (Ozimet and Miles, 2011).

where x denotes the focal subsidiary and y either host country industrial firms or research institutions. If y equals industrial firms, then the variable measures *geographical distance from industrial knowledge sources*, if it equals research institutions, then it measures *geographical distance from research knowledge sources*. AD_M, AD_S and AD_C are the average distances between the focal subsidiary and the host country sources located in the same MSA as the focal subsidiary, in the same State as the focal subsidiary, elsewhere in US, respectively. For an effective knowledge sourcing, the distance between the recipient and a source within the same MSA, State or elsewhere in the country does matter (Singh and Marx, 2013). To disentangle situations where AD_M is 0 because there are no MSA-based knowledge sources from situations where all MSA-based knowledge sources share the same location of the focal patents leading to a travel distance equal 0, we have rescaled each average distance by 1. In addition, each of these distances is weighted by the intensity of the knowledge sourcing from each of the three geographical units. That is, p_{iM}, p_{iS} and p_{iC}, which are, respectively, the share of backward citations from host country sources located in the focal subsidiary's MSA, in the focal subsidiary's State (but not in the same MSA) and elsewhere in the US over the total number of backward citations from external sources in the US. The measure is greater for large values of AD_C and smaller for large values of AD_M and takes intermediated values for large values of AD_S. For those observations corresponding to focal patents that report no US-based backward citations, we set both independent variables to 0 and define a dummy variable "*No US backward*" that equals to 1, in order to account for these special cases (Singh, 2008).

Controls

To rule out the effect of knowledge sources other than the those in the host country on subsidiaries innovation quality and generality (Phene and Almeida, 2008), we include in our models a number of controls. In particular, we account for the importance of relying on the MNC internal technology base for subsidiary innovation performance (Phene and Almeida, 2008; Singh, 2008) with the variable *internal knowledge sourcing*, which is calculated as the total number of citations the subsidiary's focal patent had referenced to patents assigned to the subsidiary's MNC (taken as logarithm plus 1). In addition to MNC-internal knowledge sourcing, subsidiaries may also assimilate knowledge from other external sources outside the host country (Frost, 2001; Phene and Almeida, 2008). Hence, we include a control to account for the extent to which the subsidiary uses technology originating from outside the US (*non-US* *knowledge sourcing*), which we measure as the total number of citations the subsidiary's focal patent had referenced to patents assigned to organizations external to the subsidiary's MNC and whose first inventor is located outside the US (taken as logarithm plus 1). Moreover, to control for the possibility that our results are driven by the co-inventor relationships between our focal patents' inventors and the inventors of the cited patents (backward citations), we first counted all those focal-backward patent pairs featuring at least one common inventor based on data on disambiguated inventors included in the Harvard Patent Dataverse (Li et al. 2014). Then, we divided this number by the total number of relevant cited patents, to obtain an average value of the co-inventor relationships between our focal patents and the respective cited patents (*co-inventor*). Inventor team collaborative experience and ongoing personal interaction may increase the likelihood of innovation commercialization success (Bercovitz and Feldman, 2011) as well as boundary spanning search, which enable great diversity of knowledge domains involved in the innovation process (Rosenkopf and Nerkar, 2001) and, hence, the generality of the innovative outcome

Finally, in order to control for innovations that result from R&D collaborations subsidiaries entertain with external partners, we include the variable *co-assigned*, a dummy that takes the value of 1 if the subsidiary patent has more than one assignee. Collaborative R&D efforts may in fact leverage synergetic knowledge bases, thus being associated with better innovative outcomes (Belderbos et al., 2014). We run a number of robustness checks to account for other factors that may potentially influence subsidiary innovation activity, which could not be added in our main estimations due to constraints in model convergence.

RESULTS

Table 1 presents the descriptive statistics and bivariate correlations for all variables included in our models. The correlation coefficients do not raise collinearity concerns.

TABLE 1 HERE

To test H1, as our measure of *quality of subsidiary innovation* is a count variable, we estimate negative binomial regression models, which correct for the presence of overdispersion (Almeida and Phene, 2004; Phene and Almeida, 2008). To test H2, as *generality of subsidiary innovation* is bounded between 0 and 1, we use two-sided tobit regression models. For both sets of models, as several patents developed by different subsidiaries belonging to the same MNC might be correlated, an issue of possible nonindependence among the observations may arise (Greene, 2000). Thus, we use Stata's cluster option to obtain a robust variance estimate that adjusts for within-cluster correlation (Williams, 2000). Moreover, we standardize our independent variables before squaring them.

Table 2 reports the findings for *quality of subsidiary innovation*.

TABLE 2 HERE

In Model 1, we test our baseline where all controls are included. In Model 2, we introduce *geographical distance from industrial knowledge sources*, which, as expected, has a positive (0.049) and statistically significant ($p<0.05$) coefficient. In Model 3, we include the squared term of *geographical distance from industrial knowledge sources* to empirically rule out a curvilinear effect on the *quality of subsidiary innovation.* In this model, the coefficient of *geographical distance from industrial knowledge sources* remains positive (0.051) and statistically significant ($p<0.05$), while the coefficient of the squared term is not significant. Hypothesis 1 is supported. In all models *geographical distance from research knowledge sources* is also non significant. Among the controls, *co-inventor* and *co-assigned* have a positive and significant effect ($p<0.05$ and $p<0.01$, respectively) on the quality of subsidiary innovation in all models, in line with established literature. Conversely, *internal knowledge sourcing* and *non-US knowledge sourcing* do not seem to have a significant effect on the quality of subsidiary innovation although their coefficients are consistent with extant research.

Table 3 presents the findings for *generality of subsidiary innovation*.

TABLE 3 HERE

In Model 1, we test our baseline where all controls are included. In Model 2, we introduce *geographical distance from research knowledge sources*, which has a positive (0.047) and statistically significant ($p<0.01$) coefficient. In Model 3, we include the squared term *geographical distance from research knowledge sources*. The coefficient of the linear term remains positive (0.154) and statistically significant ($p<0.01$) and the coefficient of the squared term is negative (-0.040) and statistically significant ($p<0.05$). Hypothesis 2 is supported. Among the controls, *co-assigned* has a positive and statistically significant ($p<0.01$) coefficient in all models. None of the other controls is significant, but their signs are overall consistent with existing literature's predictions.

Robustness checks

We performed a number of robustness checks to validate our main results.

In a first set of robustness checks we estimated our models using alternative specifications of both our dependent variables. As far as *quality of subsidiary innovation* is concerned, we first computed the measure based on the focal patent's number of forward citations by excluding self-citations (i.e., citations referenced by the same assignee), which could have a different meaning from external citations (Sørensen and Stuart, 2000) or could be used for defensive reasons by the innovating company (Hall and Ziedonis, 2001). Second, we recalculate our dependent variable considering a shorter time frame (i.e., 2 rather than 3 years from the focal patent's application date). Third, we follow established research (Tong and Frame, 1994; Lanjouw and Schankerman, 1999; Gunther Mcgrath and Nerkar, 2004; Nerkar and Parachuri, 2005; Srivastava and Gnyawali, 2011) and measure *quality of subsidiary innovation* with the focal patent's number of claims. Claims serve the objective to describe the patented invention's technological novelty (Lerner, 1994; Lanjouw and Schankerman, 2004), and thus mark the boundaries of the exclusive property rights granted by the patent. Patents with a higher number of claims are more likely to be infringed by third parties, a condition that increases the value of the patent for the innovator (Lanjouw and Schankerman, 2001). As far as *generality of subsidiary innovation* is concerned, we recalculate this measure by considering a longer time frame (i.e. 6 rather than 5 years from the focal patent's application date as in Mowery and Ziedonis (2002) and Sterzi (1999)).

A second group of robustness checks concerns the controls, which we have to limit in the main estimations because of model convergence constraints. To remedy to this, for both dependent variables we re-estimate different sets of regressions where we replace *co-assigned* with different controls.

Initially, we focus on the effect of knowledge sources others than the one under investigation. First, we recalculate the original controls for *internal knowledge sourcing* and *non-US knowledge sourcing* as ratios of the number of citations to – respectively - patents assigned to the subsidiary's MNC and external organizations whose first inventor is located outside the US, over the total number of citations. Then, we unpack the variable *non-US knowledge sourcing* to disentangle the effects of knowledge sourced from the home country and from other countries (Phene and Almeida, 2008). In particular, we include *home country knowledge sourcing* and *other countries knowledge sourcing*, measured as the total number of citations the subsidiary's focal patent had referenced to patents assigned to external (non-MNC) organizations and whose first inventor is located, respectively, in the MNC home country and other countries (taken as logarithm plus 1).

In addition, we focus on factor related to subsidiary ownership, capability and location that may influence the quality and generality of subsidiary innovation. We account for MNC's innovativeness (*MNC patent stock*), calculated as the total number of semiconductor patents successfully applied for by the focal subsidiary's MNC in the 4 years prior to the focal patent's application year (as logarithm) (Singh, 2008). We also test the robustness of our results by including a dummy variable that takes the value of 1 when the home country of the MNC is a European country, and 0 if it is an Asian country, in order to control for differences in cultural influences (Michailova and Hutchings, 2006). Then, we consider the role of subsidiary capabilities, as more capable subsidiaries may be better positioned to source distant or more basic knowledge. Hence, we draw on Singh (2008) and add a variable (*subsidiary technological capabilities*) calculated as the total number of semiconductor patents successfully applied for by the focal subsidiary in the 4 years prior to the focal patent's application year (as logarithm). To identify the subsidiary patents, we aggregated the semiconductor patents granted to the MNC by MSAs, relying on the first inventor's address. Finally, we account for the role of the MSA/CMSAs where the subsidiary is located as in MSAs/CMSAs with a higher amount of specialized knowledge are likely to benefit more the subsidiary through local knowledge spillovers. To this end, following the approach by McCann and Folta (2011) we include *region patent leadership*, which we built in two steps. In the first step, for every year included in our sample, we ranked all US MSAs/CMSAs by the cumulative sum of semiconductor patents successfully applied for by region-based inventors (considering the patent's first inventor location). In the second, we build a dummy variable that takes value of 1 for MSAs/CMSAs that are in the upper quartile (or 75th percentile) of this ranking in the year prior to the focal patent application.

As a final test, in a third set of regressions, we account for the size of the inventor team, which can affect the innovation performance through different mechanisms, such as specialization economies or access to more diversified competences (Singh, 2008). To this end, in the model we included *team size*, calculated as the total number of inventors listed in each focal patent document (as logarithm).

In all these alternative specifications, our findings are supported.[6]

DISCUSSION

Innovation within the MNC increasingly takes place in foreign subsidiaries, which devote large efforts to source diverse types of knowledge in their respective host countries to increase their innovation performance (Phene and Almeida 2008). Effective knowledge sourcing requires successful transmission and sharing of knowledge, which greatly depend on the geographical distance between source and recipient (Gertler, 2003). We connect to this idea and investigate the effect of the geography of host country knowledge sourcing by foreign subsidiaries on the subsidiary quality and generality of innovation. To this end, we account for the continuous nature of geographical distance and the heterogeneity of the host country sources. Our theoretical argument and empirical analysis suggest that foreign subsidiary benefit most from host country knowledge sourcing when they are far away from host country industrial sources, but not too distant from host country research sources. In addition, the sourcing from each of these host country actors influences specific dimensions of the subsidiary innovation outcome. Specifically, knowledge sourcing from research institutions impacts on the generality of subsidiary innovation, while knowledge sourcing from industrial firms on the quality.

Our study advances research on foreign subsidiary knowledge sourcing by offering three contributions.

First, we theoretically suggest that the concept of geographical distance is continuous in nature as knowledge spillovers appear to progressively decay with geographical distance, but also the originality of ideas and expertise that can be sourced increases with the geographical distance between source and recipient. The large literature investigating external knowledge sourcing by foreign subsidiaries has mainly compared home and host country knowledge sourcing (Almeida, 1996; Frost, 2001; Criscuolo et al., 2005) or focused on specific features of the host country as a whole (Almeida and Phene, 2004). In these studies, the geographical distance between the subsidiary and the external sources has been accounted for in terms of co-location of source and recipient (Almeida et al. 2003, Frost 2001). Yet, looking at the geography of host external sources mainly in terms of discrete discontinuity fails to account for a

[6] All additional estimations are not reported for reason of space, but available from the authors upon request.

number of situations in between 0 and 1, which could have eventually a differentiated impact on the effectiveness of the knowledge sourcing. We reflect these theoretical arguments in a continuous measure of distance that accounts for spatial continuity within and across different geographical units. By overcoming the definition of distance in terms of a binary discontinuity, we are able to conceive and capture differential effects of the geography of knowledge sourcing. Specifically, we suggest that these effects may be linear or curvilinear depending on the innovation outcome and type of source.

This last aspect closely connects to our second contribution. By unpacking the host country knowledge sources into industrial firms and research institutions we suggest that differentiating host country sources bears theoretical relevance in order to have a more nuanced understanding of the knowledge sourcing effects. Although extant research widely acknowledge that MNC subsidiaries can assimilate knowledge from multiple host country sources, the heterogeneity of host country knowledge sources has been overlooked and no differential effects have been theoretically suggested and empirically tested in relation to the multiple actors and, hence, potential sources in the host country. In particular, we submit that the heterogeneity of host country sources activates diverse sourcing mechanisms, which show varying sensitivity to space.

Third, we advance research on international knowledge sourcing by differentiating subsidiary innovation performance. Extant research has looked at the scale and only more recently at the quality of subsidiary innovation output (Phene and Almeida 2008). However, the central role the subsidiary plays in the innovation process of the entire MNC increasingly favors an innovation race within the MNC network where each unit tends to excel on dimensions of innovation others than quantity. In addition to innovations that have greater value, those that have greater applicability enhance the visibility of the innovative subsidiary within the MNC network and shorten the subsidiary's way toward becoming a center of excellence. Based on these premises we suggest that it is theoretically relevant to disentangle the multi-dimensional and complex nature of innovation to assess the influence of host country knowledge on innovation dimensions such as quality and generality.

A number of data limitations in our analysis offer opportunities for future research. First, we distinguish different host country knowledge sources based on the NBER type of classification, but we are not able to measure the actual content of the knowledge base of industrial firms and research institutions. Second, we are not able to account for changes in the formal organization of R&D within the MNCs in our sample. Such changes could affect the subsidiaries' knowledge sourcing strategies (Singh, 2008). Data limitations also prevented us to account for different subsidiary mandates (Cantwell and Mudambi, 2005) although we control for subsidiary sourcing capabilities in our additional estimations. More informative datasets supplementing patents with survey data may shed lights on these issues. Third, our empirical focus on the semiconductor industry ensures that patent data are a relevant and comprehensive source of information to analyze the innovative activities of companies operating in this sector. We are, therefore, able to offer insights on the patterns of knowledge sourcing in high-tech industry contexts, but our focus on this type of context limits the generalizability of our findings to other industries. Future research could test our arguments on different contexts. Despite these limitations, we are confident that our study contributes to advance our knowledge of the implications of subsidiary's host country knowledge sourcing on the subsidiary innovation performance.

REFERENCES

Adams, J.D., 2002. Comparative localization of academic and industrial spillovers. Journal of Economic Geography 2, 253–278.

Adams, J.D., Jaffe, A.B., 1996. Bounding the effects of R&D: an investigation using matched establishment-firm data. The RAND Journal of Economics 27, 700–721.

Agarwal, R., & Ohyama, A. (2013). Industry or academia, basic or applied? Career choices and earnings trajectories of scientists. *Management Science*, 59(4), 950-970.

Agrawal, A., Cockburn, I., McHale, J., 2006. Gone but not forgotten: labor flows, knowledge spillovers, and enduring social capital. *Journal of Economic Geography* 6 (5), 571–591.

Alcácer, J. (2006). Location choices across the value chain: How activity and capability influence collocation. Management Science, 52(10), 1457–1471.

Alcacer, J., Gittelman, M., 2006. Patent citations as a measure of knowledge flows: the influence of examiner citations. Review of Economics and Statistics 88 (4), 774–779.

Alcácer, J., and Zhao, M. (2012). Local R&D strategies and multilocation firms: The role of internal linkages. *Management Science*, *58*(4), 734–753.

Almeida, P. (1996). Knowledge sourcing by foreign multinationals: Patent citation analysis in the US semiconductor industry. *Strategic Management Journal*, *17*(S2), 155–165.

Almeida, P., Dokko, G., & Rosenkopf, L. (2003). Startup size and the mechanisms of external learning: increasing opportunity and decreasing ability?. *Research Policy*, 32(2), 301-315.

Almeida, P., and Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks. *Management Science*, *45*(7), 905–917.

Almeida, P., and Phene, A. (2004). Subsidiaries and knowledge creation: The influence of the MNC and host country on innovation. *Strategic Management Journal*, *25*(8/9), 847.

Amin, A., and Cohendet, P. (2004). *Architectures of Knowledge: Firms, Capabilities, and Communities*. Oxford: Oxford University Press.

Argyres NS, Silverman BS. 2004. R&D, organization structure, and the development of corporate technological knowledge. *Strategic Management Journal* , August–September Special Issue 25: 929–958.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. In *The rate and direction of inventive activity: Economic and social factors* (pp. 609-626). Princeton University Press.

Arts, S., & Veugelers, R. (2015). Technology familiarity, recombinant novelty, and breakthrough invention. Industrial and Corporate Change, 24 (6): 1215-1246.

Audretsch, D. B., and Feldman, M. P. (1996). R&D spillovers and the geography of innovation and production. *The American Economic Review*, 86(3), 630-640.

Bartlett, C.A., Ghoshal, S., 1986. Tap your subsidiaries for global reach. *Harvard Business Review*. 64 (4), 87–94.

Bathelt, H., Malmberg, A., and Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28(1), 31– 56.

Belderbos, R., Cassiman, B., Faems, D., Leten, B., & Van Looy, B. (2014). Co-ownership of intellectual property: Exploring the value-appropriation and value-creation implications of co-patenting with different partners. *Research Policy*, 43(5), 841-852.

Bercovitz, J., & Feldman, M. (2011). The mechanisms of collaboration in inventive teams: Composition, social networks, and geography. *Research Policy*, 40(1), 81-93.

Beugelsdijk, S. & Mudambi, R. 2013. MNEs as border-crossing multi-location enterprises: The role of discontinuities in geographic space. *Journal of International Business Studies*, 44(5): 413-26.
Blomkvist, K., Kappen, P. and Zander, I. 2010. Quo Vadis?: The entry into new technologies in advanced foreign subsidiaries of the multinational enterprise, *Journal of International Business Studies*, vol. 41, no. 9, pp. 1525-1549.
Branstetter, L. (2006). Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States. *Journal of International Economics*, *68*(2), 325–344
Breschi, S., & Lissoni, F. (2004). *Knowledge Network From Patent Data: Methodological Issues and Target Research,* CESPRI. Milan, Working Paper.
Cameron, A. C., & Trivedi, P. K. 1998. *Regression analysis of count data.* Cambridge, U.K.: Cambridge University Press.
Cantwell, J. (1995). The globalisation of technology: what remains of the product cycle model?, *Cambridge Journal of Economics*, 19(1-4): 155-174.
Cantwell, J., and Mudambi, R. (2005). MNE competence creating subsidiary mandates. *Strategic Management Journal*, *26*(12), 1109–1128.
Cantwell, J., and Santangelo, G. D. (1999). The frontier of international technology networks: sourcing abroad the most highly tacit capabilities. *Information Economics and Policy*, 11(1), 101-123.
Cantwell, J., and Santangelo, G. D. (2002). M&As and the global strategies of TNCs. *Developing Economies*, 40(4), 400-434.
Chesbrough, H. (2003) Open Innovation (Cambridge, MA: Harvard University Press).
Cohen W.M. and Levinthal D.A. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, 128-152.
Collinson, S. C., & Wang, R. (2012). The evolution of innovation capability in multinational enterprise subsidiaries: Dual network embeddedness and the divergence of subsidiary specialisation in Taiwan. *Research Policy*, 41(9), 1501-1518.
Criscuolo, P., Narula, R., Verspagen, B., 2005. Measuring knowledge flows among European and American multinationals: a patent citation analysis. *Economics of Innovation and New Technologies* 14, 417–433.
Czarnitzki, D., Hussinger, K., & Schneider, C. (2012). The nexus between science and industry: evidence from faculty inventions. *The Journal of Technology Transfer*, 37(5), 755-776.
Fogarty, M., Jaffe, A. & Trajtenberg M. (2000). The meaning of patent citations: Report of the NBER/Case-Western Reserve Survey of Patentees. Working Paper.
Frost, T.S. (2001). The geographic sources of foreign subsidiaries' innovations. *Strategic Management Journal*, *22*(2), 101–124.
Frost, T.S., Birkinshaw, J.M., and Ensign, P.C. (2002). Centers of excellence in multinational corporations. *Strategic Management Journal*, 23(11), 997–1018.
Frost, T.S., Zhou, C., 2005. R&D co-practice and 'reverse' knowledge integration in multinational firms. Journal of International Business Studies 36, 676–687.
Gambardella, A., Harhoff, D. and B. Verspagen, (2008) "The Value of European Patents", *European Management Review*, 5(2), 69–84
Gertler, M.S. (2003). Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there). *Journal of Economic Geography*, 3(1), 75–99.
Giuri, P., M. Mariani. 2013. When distance disappears: Inventors, education, and the locus of knowledge spillovers. *Review of Economics and Statistics* 95(2): 449-463
Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., ... & Hoisl, K. (2007). Inventors and invention processes in Europe: Results from the PatVal-EU

survey. *Research Policy*, 36(8), 1107-1127.
Gittelman M, Kogut B. 2003. Does good science lead to valuable knowledge? Biotechnology firms and the evolutionary logic of patent citations. *Management Science* 49: 366–395
Greene, W. H. (2000). Econometric analysis (International edition).
Gunther McGrath, R., & Nerkar, A. (2004). Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. *Strategic Management Journal*, 25(1), 1-21.
Gupta, A. K., and Govindarajan, V. (1994). Organizing for knowledge flows within MNCs. *International Business Review*, 3(4), 443-457.
Hall B, Jaffe A, Trajtenberg M. 2000. Market value and patent citations: a first look. NBER Working Paper 7741.
Hall B, Jaffe AB, Trajtenberg M. 2001. *The NBER patent citations data file: lessons, insights and methodological tools*. *NBER Working paper* no. 8498. National Bureau of Economic Research: Cambridge, MA.
Hall, B. H., Jaffe, A., and Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics*, 16-38.
Hall B, R.H. Ziedonis. 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the US. *The Rand Journal of Economics*, 32(1): 101–128.
Hannigan, T. J., Cano-Kollmann, M., & Mudambi, R. (2015). Thriving innovation amidst manufacturing decline: the Detroit auto cluster and the resilience of local knowledge production. *Industrial and Corporate Change*, 24(3), 613-634.
Harhoff, D., Narin, F., Scherer, F.M., Vopel, K., 1999. Citation frequency and the value of patented inventions. *The Review of Economics and Statistics*, Vol. 81, No. 3, 511-515.
Hausman, J., Hall, B., & Griliches, Z. 1984. Econometric models for count data with an application to the patents–R&D relationship. *Econometrica*, 52(4): 909–938.
Hegde, D., Mowery, D. C., & Graham, S. J. (2009). Pioneering inventors or thicket builders: Which US firms use continuations in patenting?. *Management Science*, 55(7), 1214-1226.
Henderson, R., Jaffe, A. B., & Trajtenberg, M. (1998). Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and statistics*, 80(1), 119-127.
Jaffe, A.B., Trajtenberg, M. & Hendersen, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics*, 108: 577-598.
Kline, S.J., Rosenberg, N., 1986. An overview of innovation. In: Landau, R., Rosenberg, N. (Eds.), The Positive Sum Strategy: Harnessing Technology for Economic Growth. National Academy Press, Washington, DC, pp. 275–305.
Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3(3), 383-397.
Kuemmerle, W. (1999). The drivers of foreign direct investments into research and development – an empirical investigation, *Journal of International Business Studies*, *30*, 1–24.
Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago University Press.
Lahiri, N. (2010). Geographic distribution of R&D activity: How does it affect innovation quality?. *Academy of Management Journal*, *53*(5), 1194–1209.
Lahiri (2015). CORRIGENDUM: Geographic distribution of R&D activity: how does it affect innovation quality? *Academy of Management Journal*, 58(4), 1283-1286.
Lanjouw, J.O., Schankerman, M., 1999. The Quality of Ideas: Measuring Innovation

with Multiple Indicators. NBER Working Paper 7345.
Lanjouw, J. O., & Schankerman, M. (2001). Characteristics of patent litigation: a window on competition. *RAND Journal of Economics*, 129-151.
Lanjouw, J. O., & Schankerman, M. (2004). Patent quality and research productivity: Measuring innovation with multiple indicators. *The Economic Journal*, 114(495), 441-465.
Laursen, K., and Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal*, *27*(2), 131–150.
Lerner, J. (1994). The importance of patent scope: an empirical analysis. *The RAND Journal of Economics*, 319-333.
Li, G. C., Lai, R., D'Amour, A., Doolin, D. M., Sun, Y., Torvik, V. I., ... & Fleming, L. (2014). Disambiguation and co-authorship networks of the US patent inventor database (1975–2010). *Research Policy*, 43(6): 941-955
Lundvall B-Đ, 1988, "Innovation as a interactive process: from user ^ producer interaction to the national system of innovation", in Technical Change and Economic Theory Eds G Dosi, C Freeman, R Nelson, G Silverberg, L Soete (Pinter, London) pp 349-369
McCann, B. T., & Folta, T. B. (2011). Performance differentials within geographic clusters. *Journal of Business Venturing*, 26(1), 104-123.
McFadyen, M. A., and Cannella, A. A. (2005). Knowledge creation and the location of university research scientists' interpersonal exchange relations: Within and beyond the university. *Strategic Organization*, 3(2), 131-155.
Michailova, S., & Hutchings, K. (2006). National cultural influences on knowledge sharing: A comparison of China and Russia. *Journal of Management Studies*, 43(3), 383–405.
Moore, G. E. (1965). Cramming more components onto integrated circuits. *Electronics*, 38(8): 114–117
Mowery, D.C., Oxley, J.E., Silverman, B.S., 1996. Strategic alliances and inter-firm knowledge transfer. Strategic Management Journal 17, 77–91.
Mowery, D.C., Ziedonis, A.A., 2002. Academic patent quality before and after the Bayh-Dole Act in the United States. *Research Policy* 31 (2), 399–418.
Narula, R., & Santangelo, G. D. (2009). Location, collocation and R&D alliances in the European ICT industry. *Research Policy*, 38(2), 393-403.
Nelson, R. R. (1959). The economics of invention: A survey of the literature. *The Journal of Business*, 32(2), 101-127.
Nelson RR, Winter S. 1982. *An Evolutionary Theory of Economic Change*. Belknap Press: Cambridge, MA.
Nerkar, A., & Paruchuri, S. (2005). Evolution of R&D capabilities: The role of knowledge networks within a firm. *Management Science*, 51(5), 771-785.
Nooteboom, B. (2000) *Learning and Innovation in Organizations and Economies*. Oxford: Oxford University Press.
Ozimek, A. and Miles, D. (2011), Stata utilities for geocoding and generating travel time and travel distance information, *Stata Journal*, 11(1): 106-119
Patel, P., Vega, M. (1999). Patterns of internationalisation of corporate technology: location vs. home country advantages, *Research Policy*, 28(2-3): 145-155.
Pearce, R.D. (1999). Decentralised R&D and strategic competitiveness: Globalised approaches to generation and use of technology in multinational enterprises (MNEs). *Research Policy*, *28*(2), 157–178.
Perri, A., and Andersson, U. (2014). Knowledge outflows from foreign subsidiaries and

the tension between knowledge creation and knowledge protection: Evidence from the semiconductor industry. *International Business Review*, *23*, 63–75.
Phene, A., and Almeida, P. (2008). Innovation in multinational subsidiaries: The role of knowledge assimilation and subsidiary capabilities. *Journal of International Business Studies, 39*, 901– 919.
Rosenberg, N. (1990). Why do firms do basic research (with their own money)?. *Research Policy*, 19(2), 165-174.
Rosenberg, N. (1982). *Inside the black box: technology and economics*. Cambridge University Press.
Rosenkopf, L. and A. Nerkar (2001), 'Beyond local research: Boundary-spanning, exploration, and impact in the optical disk industry,' *Strategic Management Journal*, 22(4), 287–306.
Singh, J. (2007). Asymmetry of knowledge spillovers between MNCs and host country firms. *Journal of International Business Studies*, 38, 764–786.
Singh, J. (2008). Distributed R&D, cross-regional knowledge integration and quality of innovative output. *Research Policy*, *37*(1), 77–96
Singh, J., and Marx, M. (2013). Geographic constraints on knowledge spillovers: political borders vs. spatial proximity. *Management Science*, 59(9), 2056-2078.
Song, J., & Shin, J. (2008). The paradox of technological capabilities: a study of knowledge sourcing from host countries of overseas R&D operations. *Journal of International Business Studies*, 39(2), 291-303.
Sørensen, J. B., & Stuart, T. E. (2000). Aging, obsolescence, and organizational innovation. *Administrative Science Quarterly*, 45(1), 81-112.
Srivastava, M. K., & Gnyawali, D. R. (2011). When do relational resources matter? Leveraging portfolio technological resources for breakthrough innovation. *Academy of Management Journal*, 54(4), 797-810.
Sterzi, V. (2013). Patent quality and ownership: An analysis of UK faculty patenting. *Research Policy*, 42(2), 564-576.
Stuart, T., & Podolny, J. 1996. Local search and the evolution of technological capabilities. Strategic Management Journal, 17(7): 21–38.
Thompson, P., 2006. Patent citations and the geography of knowledge spillovers: evidence from inventor- and examiner-added citations. *Review of Economics and Statistics* 88 (2), 383–389.
Tong, X., & Frame, J. D. (1994). Measuring national technological performance with patent claims data. *Research Policy*, 23(2), 133-141.
Trajtenberg, M., 1990. A penny for your quotes: patent citations and the value of innovations. *RAND Journal of Economics* 21 (1), 172–187.
Trajtenberg M, Henderson R, & Jaffe A. 1997. University versus corporate patents: a window on the basicness of invention. *Economics of Innovation and New Technology* 5: 19–50.
Tzabbar, D., & Vestal, A. (2015). Bridging the social chasm in geographically distributed R&D teams: the moderating effects of relational strength and status asymmetry on the novelty of team innovation. *Organization Science*, 26(3), 811-829.
Valentini, G. (2012). Measuring the effect of M&A on patenting quantity and quality. *Strategic Management Journal*, 33(3), 336-346.
Vanhaverbeke, W., Chesbrough, H., & West, J. (2014). Surfing the new wave of open innovation research. *New Frontiers in Open Innovation*, 281.
Vega-Jurado, J., Gutierrez-Gracia, A. and Fernandez-de-Lucio, I., 2009. Does external knowledge sourcing mcatter for innovation? Evidence form the Spanish manufacturing industry. *Industrial and Corporate Change*, 18(4), pp. 637-670.

Williams, R. L. (2000). A note on robust variance estimation for cluster‐correlated data. *Biometrics*, 56(2), 645-646.
Zhao, M. (2006). Conducting R&D in countries with weak intellectual property rights protection. *Management Science*, *52*(8), 1185–1199.

Table 1. Correlation matrix and descriptive statistics (obs. 1,788)†

	1	2	3	4	5	6	7	8
1. N° forward citations (3-year window)	1.000							
2. Generality	-0.008	1.000						
3. Geographical distance from industrial knowledge sources	0.012	0.046	1.000					
4. Geographical distance from research knowledge sources	0.027	0.080*	0.062*	1.000				
5. (ln) Internal knowledge sourcing	0.023	-0.052	-0.028	0.029	1.000			
6. (ln) non-US knowledge sourcing	0.012	-0.013	0.136*	0.130*	0.187*	1.000		
7. Co-inventor	0.033	0.001	-0.054*	0.019	-0.018	0.033	1.000	
8. Co-assigned	0.072*	0.027	-0.088*	-0.003	-0.010	-0.073*	0.042	1.000
Mean	2.751	0.327	0.000	0.000	0.418	1.230	0.018	0.018
Std. Dev.	3.422	0.342	1.000	1.000	0.614	0.758	0.093	0.135
Min	0.000	0.000	-2.298	-0.347	0.000	0.000	0.000	0.000
Max	33.000	1.000	1.893	4.423	3.332	4.443	1.000	1.000

† Obs. for *Generality of subsidiary innovation* are equal to 1,336 (see footnote 2)..

*p<0.05.

Table 2. Negative binomial regression (dependent variable *Quality of subsidiary innovation* – obs. 1,788)†

	Model (1)	Model (2)	Model (3)
Geographical distance from industrial knowledge sources		0.049**	0.051**
		(0.023)	(0.022)
Geographical distance from industrial knowledge sources^2			-0.021
			(0.020)
Geographical distance from research knowledge sources	0.027	0.028	0.028
	(0.045)	(0.045)	(0.045)
No US backward	-0.014	0.108	0.211
	(0.064)	(0.101)	(0.131)
(ln) Internal knowledge sourcing	0.046	0.049	0.048
	(0.070)	(0.069)	(0.070)
(ln) Non-US knowledge sourcing	0.007	0.004	0.000
	(0.049)	(0.047)	(0.047)
Co-inventor	0.346**	0.389**	0.383**
	(0.176)	(0.175)	(0.172)
Co-assigned	0.509***	0.516***	0.531***
	(0.146)	(0.140)	(0.144)
Constant	0.965***	0.955***	0.971***
	(0.111)	(0.111)	(0.110)
Wald statistic	259.99***	348.43***	331.94***

†Robust standard errors corrected for heteroscedasticity and cluster-correlated data are reported in brackets.
*p<0.1 **p<0.05 ***p<0.01

Table 3. Tobit regression (dependent variable *Generality of subsidiary innovation* – obs. 1,336) †

	Model (1)	Model (2)	Model (3)
Geographical distance from research knowledge sources		0.047***	0.154***
		(0.011)	(0.048)
Geographical distance from research knowledge sources^2			-0.040**
			(0.016)
Geographical distance from industrial knowledge sources	0.034	0.036	0.041
	(0.024)	(0.025)	(0.025)
No US backward	-0.014	0.007	0.021
	(0.064)	(0.062)	(0.061)
(ln) Internal sourcing	-0.046	-0.043	-0.043
	(0.061)	(0.061)	(0.061)
(ln) Non-US knowledge sourcing	-0.009	-0.017	-0.018
	(0.046)	(0.047)	(0.047)
Co-inventor	0.011	0.009	0.016
	(0.195)	(0.204)	(0.206)
Co-assigned	0.143***	0.139***	0.144***
	(0.035)	(0.038)	(0.038)
Constant	0.185***	0.192***	0.232***
	(0.049)	(0.053)	(0.057)
F statistic	17.81***	16.69***	18.13***

579 left-censored observations at Generality<=0
686 uncensored observations
71 left-censored observations at Generality>=1

†Robust standard errors corrected for heteroscedasticity and cluster-correlated data are reported in brackets.
*p<0.1 **p<0.05 ***p<0.01